

CLAIMS:

1. A method of fabricating an electromechanical resonating device, the method comprising the steps of:
 - 5 obtaining a work piece including a substrate, a first layer born on the substrate, and a second layer born on the first layer;
 - patternwise etching the second layer to define:
 - a member capable of resonating in a vibrational mode; and
 - one or more supports mechanically coupled to the member;
 - 10 selectively doping the second layer to define one or more conductive pathways onto the member; and
 - etching a portion of the first layer beneath the member.
2. The method according to claim 1 wherein the step of obtaining a work piece comprises the sub-steps of:
 - 15 obtaining a work piece comprising:
 - a silicon wafer;
 - a silicon di-oxide layer born on the silicon wafer; and
 - a single crystal silicon layer born on the silicon di-oxide layer.
3. The method according to claim 1 wherein the step of obtaining a work piece comprises the sub-steps of:
 - 20 obtaining a silicon wafer; and
 - implanting the silicon wafer with oxygen to form a buried silicon di-oxide layer.

4. The method according to claim 1 wherein the step of obtaining a work piece comprises the sub-steps of:

5 obtaining a substrate;
forming a first layer on the substrate; and
forming a second layer on the substrate.

5. The method according to claim 1 wherein the step of obtaining a work piece comprises the sub-steps of:

10 obtaining a first wafer;
obtaining a second wafer made of a semiconductor material;
forming an oxide layer on the first wafer;
bonding the oxide layer to the second wafer; and
abrading the second wafer to reduce its thickness;
15 whereby a work piece comprising the first wafer as a substrate, the oxide layer, and a layer of the semiconductor material overlying the oxide is obtained.

6. The method according to claim 1 wherein the step of obtaining a work piece comprises the sub-steps of:

20 obtaining a first wafer;
obtaining a second wafer made of a semiconductor material;
forming an oxide layer on the second wafer;
implanting the second wafer with hydrogen to form a bubble layer below the oxide layer;
25 bonding the first wafer to the oxide layer of the second wafer to form a bonded wafer; and
heating the bonded wafer to cleave it at the bubble layer.

7. The method according to claim 1 wherein the step of patternwise etching comprises the sub-steps of:

5 patternwise etching the second layer to define a beam coupled to one or more supports.

8. The method according to claim 1 wherein the step of patternwise etching comprises the sub-steps of:

10 patternwise etching the second layer to define:
a beam comprising:
a first end edge at a first end of the beam;
a second end edge at a second end of the beam;
a first longitudinal edge extending between the first end
and the second end;
15 a second longitudinal edge extending between the first end
and the second end; and
a central region.

9. The method according to claim 8 wherein the step of patternwise etching comprises
20 the sub-steps of:

patternwise etching the second layer to define:
a first support coupled to the first longitudinal edge at a first point
that is approximately midway between the first end and the second
end; and
25 a second support coupled to the second longitudinal edge at a
second point that is approximately midway between the first end
and the second end.

10. The method according to claim 9 wherein the step of selectively doping the second layer comprises the step of:

selectively doping the second layer to define

5 a first conductive region that extends from the first support towards the first end; and

 a second conductive region that extends from the second support towards the second end; and

10 an isolation region between the first conductive region and the second conductive region.

11. The method according to claim 9 wherein the step of selectively doping the second layer comprises the step of:

selectively doping the second layer to define:

15 a first conductive region that extends from the first support to the first end;

 a second conductive region that extends from the second support to the second end; and

20 an isolation region between the first conductive region and the second conductive region.

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12. The method according to claim 8 wherein the step of patternwise etching comprises the sub-steps of:

patternwise etching the second layer to define:

- 5 a first support coupled to the first longitudinal edge at a first node of the vibrational mode;
- a second support coupled to the first longitudinal edge at a second node of the vibrational mode;
- 10 a third support coupled to the second longitudinal edge at the first node of the vibrational mode; and
- a fourth support coupled to the second longitudinal edge at the second node of the vibrational mode.

13. The method according to claim 12 wherein the step of selectively doping the second layer comprises the step of:

15 selectively doping the second layer to define:

a first conductive region that extends from the first support at least towards the central region of the beam.

20 14. The method according to claim 12 wherein the step of selectively doping the second layer comprises the step of:

selectively doping the second layer to define:

a first conductive region that extends from the first support across the central region of the beam to the second support.

15. An electromechanical resonating device comprising:
- a first support member; and
 - a selectively doped vibrating member that is capable of resonating in a vibrational mode that has a first node and is attached to the first support at a position of the first node, the selectively doped vibrating member including:
 - a first doped conducting region extending from the first support;
 - and
 - an insulating region.
16. The electromechanical resonating device according to claim 15 wherein:
- the selectively doped vibrating member comprises a body of single crystal semiconductor material.
17. The electromechanical resonating device according to claim 16 wherein:
- the support comprises a top layer of single crystal semiconductor material that is contiguous with the body of single crystal semiconductor material.
18. The electromechanical resonating device according to claim 17 wherein:
- the support is contiguous with a portion of single crystal silicon that overlies a lower layer of silicon di-oxide.
19. The electromechanical resonating device according to claim 15 wherein:
- the selectively doped vibrating member comprises a beam shaped member having a first end, and a second end, a first longitudinal side extending between the first end and the second end, and a second longitudinal side extending between the first end and the second end.

20. The electromechanical resonating device according to claim 19 wherein:

the selectively doped vibrating member is capable of resonating in a vibrational mode that includes the first node and a second node; and

5 the resonating device further comprises a second support attached at the second node.

21. The electromechanical resonating device according to claim 20 wherein:

the first doped conducting region extends from the first support to the second support.

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22. The electromechanical resonating device according to claim 20 wherein:

the first support is attached to the first longitudinal side;

the second support is attached to the second longitudinal side; and

the device further comprises:

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a third support attached to the second longitudinal side at the first node;

and

a fourth support attached to the first longitudinal side at the second node.

23. The electromechanical resonating device according to claim 19 wherein:

the first node is located at approximately a center of the beam shaped member;

5 the first support is attached at approximately a center of the first longitudinal side of the beam shaped member; and

the first doped conducting region extends from the first support towards the first end of the beam shaped member; and

the resonating device further comprises:

10 a second support attached at approximately the center of the second longitudinal side of the beam shaped member; and

a second doped conducting region extending from the second support toward the second end of the beam shaped member; and

15 an insulating region between the first doped conducting region and the second doped conducting region.

24. The electromechanical resonating device according to claim 23 wherein:

the selectively doped vibrating member is capable of resonating in a vibrational mode that includes the first node, a second node, and a third node; and

20 the resonating device further comprises;

a third support attached to the beam at the second node;

a fourth support attached to the beam at the third node.

25. The electromechanical resonating device according to claim 23 wherein:

25 the first doped conducting region extends from the first support to the third support; and

the second doped conducting region extends from the second support to the fourth support.

26. An electromechanical resonating system comprising:
vibrating member that is capable of resonating in a vibrational mode that includes
a first anti-node characterized by a first relative phase and a second anti-node
characterized by a second relative phase that is opposite to the first phase; and
5 a first electrode positioned in a vicinity of the first anti-node; and
a second electrode positioned in a vicinity of the second anti-node.
27. The electromechanical resonating system according to claim 26 further
comprising:
10 a circuit coupled to the first electrode and second electrode;
whereby a signal can be propagated through the vibrating member.
28. The electromechanical resonating system according to claim 26 comprising
an electric circuit including:
15 a first differential input coupled to the first electrode; and
a second differential input coupled to the second electrode.
29. The electromechanical resonating system according to claim 28 wherein:
the electric circuit comprises:
20 a differential amplifier.
30. The electromechanical resonating system according to claim 26 wherein:
the first electrode comprises:
a first selectively doped region of the vibrating member.
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31. The electromechanical resonating system according to claim 30 wherein:
the second electrode comprises:
a second selectively doped region of the vibrating member.

32. The electromechanical resonating system according to claim 26 wherein:
the vibrating member comprises:
a beam capable of vibrating in a flexural mode having at least two anti-nodes, and
one or more nodes.
33. The electromechanical resonating system according to claim 26 wherein:
a longitudinal coordinate of a center of gravity of the beam corresponds to a position
of one of the one or more nodes.
34. The electromechanical resonating system according to claim 33 comprising:
an electric circuit including:
a first differential input coupled to the first electrode; and
a second differential input coupled to the second electrode.
35. The electromechanical resonating system according to claim 26 further
comprising:
one or more supports coupled to the beam at each of the one or more nodes.
36. The electromechanical resonating system according to claim 26 wherein:
the vibrating member comprises a beam capable of vibrating in a flexural mode
having at least three anti-nodes, and two or more nodes.
37. The electromechanical resonating system according to claim 36 wherein:
the vibrating member comprises a beam capable of vibrating in a flexural mode
having an even number of anti-nodes including a first plurality of anti-nodes
characterized by the first phase, and a second plurality of anti-nodes characterized by
the second phase.

38. The electromechanical resonating system according to claim 37 comprising:
a first set of electrodes each positioned in the vicinity of one of a set of the first
plurality of anti-nodes; and
5 an electric circuit including:
a first input coupled to the first set of electrodes.

39. The electromechanical resonating system according to claim 38 further
comprising:

10 a second set of electrodes each positioned in the vicinity of one of a set of the
second plurality of anti-nodes; and
a second input of the electric circuit coupled to the second set of electrodes.

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40. A method of fabricating an electromechanical resonating device, the method comprising the steps of:

- 5 obtaining a semiconductor wafer having a surface; and
etching one or more deep trenches in the wafer to define a vibrating plate oriented perpendicular to the surface.

41. The method according to claim 40 wherein the step of etching, comprises the sub-steps of:

- 10 etching a first deep trench in the surface; and
etching a second deep trench in the surface parallel to the first deep trench.

42. The method according to claim 40 wherein the step of etching, comprises the sub-step of:

- 15 etching a closed curve plan trench in the surface.

43. The method according to claim 40 wherein the step of etching comprises the sub-step of:

- 20 etching a rectangular plan trench in the surface.

44. The method according to claim 40 wherein the step of etching, comprises the sub-step of:

- etching a open curve plan trench in the surface.

25 45. The method according to claim 40 wherein the step of etching, comprises the sub-step of:

- etching a U-shaped plan trench in the surface.

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49. An electromechanical resonating device comprising:

a semiconductor chip including:

a first surface

5 a vibrating plate formed in the first surface and oriented perpendicular to the first surface;

a first trench peripheral to the vibratable plate; and

10 one or more electrodes located near the vibratable plate for coupling electrical signals to and from the vibratable plate and causing the vibratable plate to vibrate.

50. The electromechanical resonating device according to claim 49 wherein:

the first trench comprises a corrugated wall portion; and

15 the one or more electrodes comprise one or more selectively doped inwardly projecting corrugations of the corrugated wall.

51. The electromechanical resonating device according to claim 49 wherein the vibratable plate includes a conductivity increasing dopant.

20 52. The electromechanical resonating device according to claim 49 wherein:

the first trench has a rectangular plan view; and

the vibratable plate includes:

a bottom edge coupled to the semiconductor chip;

a free first side edge;

25 a free second side edge; and

a free top edge.

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53. The electromechanical resonating device according to claim 49 further comprising:

a second trench located on a second side of the vibratable plate; and

wherein:

the first trench is located on a first side of the vibratable plate; and

the vibratable plate includes:

a bottom edge connected to the semiconductor chip;

a first side edge connected to the semiconductor chip;

a second side edge connected to the semiconductor chip; and

a free top edge.

54. The electromechanical resonating device according to claim 49 wherein:

the first trench has a U-shaped plan view; and

the vibratable plate includes:

a bottom edge connected to the semiconductor chip;

a first side edge connected to the semiconductor chip;

a free second side edge; and

a free top edge.

55. The electromechanical resonating device according to claim 49 wherein the one or more electrodes includes:

one or more pairs of electrodes, each of which includes a first electrode that is positioned on a first side of the vibratable plate and coupled to a signal source for receiving a first phase of a periodic signal, and a second electrode that is positioned on a second side of the vibratable plate and is coupled to the signal source for receiving a second phase of the periodic signal, that differs from the first phase by half a cycle of the periodic signal.

56. The electromechanical resonating device according to claim 55 wherein the one or more electrodes includes:

a first pair including:

5 a first electrode that is positioned on the first side of the vibratable plate and coupled to the signal source for receiving the first phase of the periodic signal; and

a second electrode that is positioned on the second side of the vibratable plate; and

a second pair including:

10 a third electrode that is positioned on the first side of the vibratable plate and coupled to the signal source for receiving the second phase of the periodic signal; and

15 a fourth electrode that is positioned on the second side of the vibratable plate.

FIG. 4 is a schematic diagram of the electromechanical resonating device according to claim 56.